SYSTEM FOR ADJUSTING A PHOTO-EXPOSURE TIME

This application relies for priority upon Korean Patent Application No. 2000-17986, filed on April 6, 2000, the contents of which are herein incorporated by reference in their

5 entirety.

BACKGROUND OF THE INVENTION

This invention relates to a photolithography system and process for manufacturing a semiconductor device. More particularly, this invention relates to a system for adjusting

10 a photo-exposure time suitable for variable processing conditions in accordance with prior and following steps.

The greater a semiconductor device is integrated, the more line widths on the device must be narrowed. Furthermore, as the line width is reduced, more accurate alignment is required for patterns of stacked layers formed through a manufacturing

15 process for the semiconductor device. Of all of the various pieces of equipment required for manufacturing semiconductor devices, a photo-exposure apparatus is the most important for determining the alignment accuracy for the stacked layers. In other words, in modern semiconductor manufacturing, a photo-exposure apparatus must have improved capacities for high resolution and fine alignment so as to be capable of

20 manufacturing highly-integrated semiconductor devices.

Various techniques have been used for highly efficient photo-exposure apparatuses. For example, in order to enhance the alignment accuracy in semiconductor

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device manufacturing technology and to uniformly obtain a fine pattern in an accurate

position, conventional G-Line light sources, with a wavelength of 436 nm, are gradually

being replaced by I-Line light sources, with a wavelength of 365nm, or deep ultra violet

light sources, with a wavelength of 248nm. Furthermore, a scanner-type source is

5   dominantly being used rather than a stepper-type source.

There are several factors, such as a kind of lens system used or the light source

used that influence the accuracy of a photo-exposure apparatus. In addition, an exposure

time adjusting method, the kind and thickness of a photoresist material used, the baking

conditions, the developing conditions, etc. may also effect the resultant quality of a photo-

10   exposure work. In particular, a photo-exposure time is a very important parameter to

finalize a line width and a uniformity of the pattern geometry. This is because photo-

exposure time has an effect at the amount of a photochemical reaction of photoresist at an

edge of a pattern image formed on a photoresist film.

Accordingly, although a line width of a pattern is primarily determined by the line

15   width of a photo-exposure mask and a geometric optical configuration of a photo-

exposure apparatus, a line width of a photoresist pattern may be also adjusted by

controlling the photo-exposure time within a small range.

When controlling a photo-exposure time, it is necessary to first evaluate the size

and quality of a photoresist pattern obtained from a previous photo-exposure time. Then,

20   a photo-exposure time can be re-established by a kind of processing feedback according

to this evaluation. In other words, an evaluation of a post-exposure step is fed back to a pre-exposure step, so that the pre-exposure step processing condition can be adjusted.

An example of the above technology is disclosed in U.S. patent No. 5,965,309. In this patent, a size and a shape of a resulting pattern obtained from a conventional

5   patterning process using a photolithography and an etching are first evaluated. The evaluated result is then progressed, and a processing condition is re-established by means of a predetermined method to influence the patterning. In particular, a method is disclosed that is effective on a final pattern by adjusting a focus and an exposure rate in a photo-exposure process, in addition to the method of adjusting a condition in an etching

10   process.

Although the above patent deals widely with techniques for conditioning photo-exposure and etching steps by adjusting patterning conditions through feedback, it does not clearly consider that a photo-exposure rate would be influenced by adjusting a photo-exposure time.

15   Meanwhile, a photoresist pattern obtained as a result of a photo-exposure work may be evaluated by an after-development inspection (ADI). Of course, the photoresist pattern is affected not only by various processing conditions directly related to a photo-exposure but also by a result of a pre-exposure step.

For example, if a film stacked before a photo-exposure process is made of a

20   material having a characteristic of reflecting light well or preventing reflection, a photoresist pattern on the film is influenced by the preformed film. Certain parts of a

photoresist pattern formed by a photo-exposure may be influenced by the topological pattern of a substrate surface, e.g., an uneven step coverage, formed before a photo-exposure process, or by a relative pattern position obtained after a photo-exposure process.

5   However, a current system for adjusting photo-exposure time cannot systematically apply a status of a result pattern or a pre-exposure step into the photo-exposure process. In addition, it has been problematic that a photoresist pattern position and a line width obtained after a photo-exposure process are variable based on the state of the power applied to a substrate.

10   Furthermore, in almost any manufacturing system it is necessary to periodically carry out data collection and evaluation in order use parameters obtained by a process evaluation result for the modification of a processing condition. However, it is not easy to maintain suitable processing condition in many cases while the data collection and evaluation are being carried out.

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SUMMARY OF THE INVENTION

An object of the invention is to resolve the above problems. In other words, it is an object of the present invention to provide a system for adjusting a photo-exposure time by using a result of a photo-exposure process.

20   Another object is to provide a system for adjusting a photo-exposure time capable of enhancing a uniformity of a photoresist pattern by reflecting a feedback of factors to be

compensated obtained from a post-exposure evaluation of the photo-exposure result and a feed forward of factors to be cured, obtained before a photo-exposure process.

In order to obtain the above objects, a system for adjusting a photo-exposure time in a semiconductor manufacturing apparatus, the system comprises a photo-exposure unit

5 for adjusting a photo-exposure time of a photo-exposure step performed on a semiconductor device in the semiconductor manufacturing apparatus, in accordance with one or more adjustment signals; a pre-exposure step influence prediction unit for obtaining information about a semiconductor device in the manufacturing apparatus during a pre-exposure processing, prior to the device being subjected to the photo-

10 exposure step, the information including a value of a factor that will influence a line width of a line formed on the semiconductor device in the photo-exposure step, and providing that information as feed forward data; an inspection unit for generating an inspection value by measuring an aspect of the semiconductor device after it has been subjected to the photo-exposure step, and providing the inspection value as feed back

15 data; and a central processing unit for receiving the feed forward data and the feed back data, and generating the one or more adjustment signals based on the feed forward data and the feed back data.

The feed forward data is preferably obtained by quantifying the obtained information. One or more adjustment signals are preferably transmitted to the photo-

20 exposure unit by the central processing unit in a real time.

The one or more adjustment signals are preferably generated through the use of a calculation formula, and the calculation formula preferably weights the feed forward and feed back data.

The central processing unit preferably comprises a database containing
5 information obtained from the photo-exposure unit, the pre-exposure step influence prediction unit, and the inspection unit.

The feed forward data preferably pertains to the thickness of a film formed in processing of the pre-exposure step. The film is preferably a reflection barrier layer formed in the pre-exposure step.

10 The photo-exposure unit can be made to adjust a photo-exposure time based on the adjustment signals received from the central processing unit.

The pre-exposure step influence prediction unit obtains pre-exposure step processing information for a semiconductor substrate to be processed in the photo-exposure unit. Based on this information, the pre-exposure step influence prediction unit
15 extracts the values of parameters to affect the width of a line formed in the photo-exposure unit. Furthermore, if the extracted values are difficult to be processed, the values may be quantified by a predetermined logical method. The pre-exposure step influence prediction unit stores the extracted or quantified values as feed forward data to be provided to the central processing unit.

20 The inspection unit checks and stores a pre-exposure step result from the photo-exposure unit. In other words, it checks a line width value for a semiconductor substrate

formed in the photo-exposure unit. Instead of the pre-exposure step result value, the inspection unit may store a differential value obtained by comparing the pre-exposure step result value with a target value formed for a pre-exposure step processing. The stored values are then used as feed back data. In case a value to be compared is stored as

5   a feed back data, a target value for a pre-exposure step should be input to the inspection unit.

The central processing unit receives data from the pre-exposure step influence prediction unit and the inspection unit. These data are applied to a predetermined programmed calculation method and are used to generate the adjustment signals. In many

10   cases, the adjustment signals include a differential value to be corrected considering a pre-step photo-exposure time in the photo-exposure unit. Alternatively, an adjustment signal could be an optimal photo-exposure time itself.

The adjustment signal is transferred to the photo-exposure unit as intact or converted signals adaptable to the photo-exposure unit. It is desirable to transmit the

15   signals in a real time before a semiconductor substrate is processed, to prevent some substrates from being exposed during an inappropriate photo-exposure time.

It is preferable to apply a predetermined calculation method to the central processing unit in the present invention considering a processing status. For instance, the data to be calculated in the predetermined method is stored in the inspection unit or the

20   pre-step influence prediction unit. Among the stored data, the most recent data result may

have a weighted value. In this case, the weighted value may be inputted together with the data to be calculated.

The processing steps in this invention are performed on substrate lots because the substrates in the same lot are treated by the same conditions. The three most recent lots

5   of the processed substrates in the photo-exposure unit may be inspected so as to obtain a pre-step result. A photo-exposure time value for correction by a predetermined calculation method corresponds to a differential value for line width obtained from analyzing differential values for line widths from the previous three lots. Furthermore, a time value for correction corresponding to feed forward data may be also considered for a

10 calculation of the time value for correction.

The photo-exposure result of multiple pre-exposure steps, i.e., accumulated data of line width values after development may be used for evaluating the influence of pre-exposure steps. For example, line width values are arranged in the ADI step for each prior processed lot. In the pre-exposure steps of each prior process, factors influencing a

15 photo-exposure process are determined and the values are quantified.

The relation between line width values and quantified factor values may be arranged by a graph or a function. Instead of the line width values, the differential value from a line width value and a target value of the line width may be used for obtaining the relationship. When a graph or a function related to a line width from the factor values is

20 obtained, the relationship is reflected in the predetermined calculation method.

In this invention, a reflectivity is determined by the thickness and quality of substrate surface formed in the most recent pre-exposure step process. The reflectivity may be illustrated as a factor value capable to be quantified or feed forward data.

5 **BRIEF DESCRIPTION OF THE DRAWING**

This invention may be more fully understood from the following drawings.

Fig. 1 is a schematic showing the flow of processing and information of a preferred embodiment of this invention.

Fig. 2 is a graph of a photo-exposure time and the result of after-development

10 inspection (ADI) of a line width before and after this preferred embodiment invention has been applied.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a schematic showing the flow of processing and information of a

15 preferred embodiment of this invention. In Fig. 1, double-line arrows indicate the flow of a wafer treatment and single-line arrows indicate an information processing flow.

During processing, a wafer is first provided to a pre-exposure step process. In the pre-exposure step process 10, a silicon-nitride film is preferably deposited uniformly on the surface of a wafer. Next, the wafer is provided to a photo-exposure process 20. In the

20 photo-exposure process 20, a photoresist is formed over a whole surface of the wafer, and then baking, exposing, and developing are sequentially performed. After the

development portion of the photo-exposure process, the wafer then progresses to the

after-development inspection (ADI) process 30, which inspects and measures a line width

of the photoresist pattern formed after the photo-exposure process 20. The wafer is then

transferred to the next process using a photoresist mask such as an etching or an ion

5 implantation process.

During the above processing steps, information about a relevant process condition

or process result is provided to a pre-exposure step influence prediction unit 40, a photo-

exposure unit 50, and an after development inspection (ADI) unit 60. This information is

then provided to a central processing unit 70, and is used as needed.

10 In the silicon-nitride depositing pre-exposure step process 10, the reflectivity and

thickness of the silicon-nitride film, etc. act as parameters that influence the photo-

exposure process. Therefore, values obtained for these factors are provided to the pre-

exposure step influence prediction unit 40.

In the photo-exposure process 20, information regarding the photo-exposure time

15 is provided to the photo-exposure unit 50 together with other conditioning parameters,

such as characteristics of the photoresist material and light source, baking temperature

and time, development conditions, and so on. It is desirable that a photo-exposure time

be classified and managed with the unique number of reticles because photo-exposure

time may vary by reticles even in the same step and equipment.

20 Throughout the whole process, the information from each step may be classified

by the reticle order for each wafer. In the alternative, however, an order extracted from

the information values corresponding to the lot numbers may be processed and stored as a representative value. In this case, the lot number is a processing unit.

In the ADI step 30, an inspection is conducted to check a line width at a predetermined region on the wafer after a single step, or on a wafer extracted as a sample out of the processing units. The value of the line width measured from the ADI step is stored in the ADI unit 60.

A measured line width value CD_n for an nth step is obtained from the ADI unit 60, and is compared with a line width target value CD_{TARGET} input to the central processing unit 70. From these two values, a differential value ΔCD_n is determined, according to equation (1).

$$\Delta CD_n = CD_{TARGET} - CD_n, \tag{1}$$

where the abbreviation "CD" stands for "critical dimension."

The differential value ΔCD is then stored in a corresponding storage location in the central processing unit 70.

In the photo-exposure process 20, a photo-exposure time, which is adjusted by a reticle, is determined to be ET_n for the nth step. In addition, a standard photo-exposure time $ET_{STANDARD}$ is provided to the central processing unit 70, based on the target value CD_{TARGET}. From these two values, a differential exposure time ΔET_n, representing a difference between the standard photo-exposure time and a real photo-exposure time for the nth step, can be determined according to equation (2).

$$\Delta ET_n = ET_{STANDARD} - ET_n \tag{2}$$

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A ratio of a variation for a line width to a variation of photo-exposure time is expressed as a constant G. The constant G may be established by averaging the ratio $\dfrac{\Delta CD_n}{\Delta ET_n}$ over a plurality of steps, e.g., as repeated 100 times.

The ratio of $\dfrac{\Delta CD_n}{\Delta ET_n}$ is summarized in equation (3) below when it is averaged over

5   100 steps. In this way, the constant G may be corrected into an optimal value regarding accumulated data in the central processing unit. Although Fig. 3 uses 100 as the number of steps for averaging, it could be higher or lower as desired.

$$G = \frac{1}{100} \sum_{n=1}^{100} \frac{\Delta CD_n}{\Delta ET_n} \tag{3}$$

Based on the above relationship, it is possible to obtain the value ΔET_n, i.e., the

10   difference of photo-exposure time, from the constant G and the ΔCD_n, by dividing ΔCD_n by G. As a result, a desired photo-exposure time value ET'_n can be obtained by such an inverse operation using the values of G and ΔCD_n.

The set photo-exposure time for the nth step is ET_n, and the photo-exposure time correction value for the nth step is ΔET_n. The desired photo-exposure time for the $(n+1)^{th}$

15   step ET'_{n+1} is then obtained by correcting the nth determined photo-exposure time by the nth time correction value ΔET_n, according to equation (4) below.

$$ET'_{n+1} = ET_n + \Delta ET_n, \tag{4}$$

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keeping in mind that the value ET'_{n+1} is determined based on an actual photo-exposure

time ET_n obtained from a desired photo-exposure time for the nth step, i.e., ET'_n, which is

set from a feed back operation with the nth processing result.

The value resulting from equation (4) may be reliable assuming no influence from

5   pre-exposure step process 10 to the $(n+1)^{th}$ step. Therefore, the result from the equation

(4) would be adaptable only to a photo-exposure process relatively free from any

influence from the pre-exposure step.

In the above equation (4), although the difference value ΔET_n is added to ET_n,

there may also be a variation to this value in accordance with light-sensitive type of

10   photoresist material used, i.e., negative or positive.

Because of this, an evaluating operation to determine an optimum photo-exposure

time that uses only feed back-parameters and is not influenced by the pre-exposure step

process 10 is not suitable for a complex process that is sensitive to a film formation in the

pre-exposure step process 10. Thus, for a manufacturing process associated with factors

15   of the complexity and sensitivity, a desired photo-exposure time ET'_n should be modified

with regard to information from the pre-exposure step process 10. In other words, it is

required for a photo-exposure time to be recognized as a function of quantified values of

factors arising from a pre-exposure step.

An example will now be described showing how to obtain the information

20   regarding the influence from the pre-exposure step process 10 in the case of that there is

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accumulated data of line width values CD_n for substrates from the ADI process 30 on which numerous pre-exposure steps have preceded.

First, an effective relation is accumulated of the profiles of the silicon-nitride film that acts as a reflection barrier layer. Then, using the accumulated data, a desired photo-

5   exposure time ET'_n is obtained and stored. This desired photo-exposure time ET'_n is required to determine a desired line width for each pre-processed lot. Also, the thickness of the silicon-nitride film, which has been formed in a pre-exposure step process of each prior task, is inspected, as are the line widths obtained from ADI when a desired photo-exposure time is used in the photo-exposure process. The relationship between the

10   thickness of silicon-nitride films and the desired photo-exposure time ET'_n is determined from the result.

It is desirable that other processing parameters are fixed while obtaining this data. However, if there are large amount of the accumulated data, the processing parameters, in the aggregate, are largely stable. Therefore, the relationship may be obtained even when

15   other processing parameters are not monitored, if multiple samples are observed.

The relation may be obtained by the central processing unit 70 a functional formula or data from a graph stored in the and the pre-exposure step influence prediction unit 40. As a result, a corrected desired photo-exposure time $ET'(t_n)$ may be obtained from the functional formula or graph. The desired photo-exposure time corresponds to

20   the thickness of silicon-nitride films on the substrate surface from a pre-exposure step processing of an nth step.

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If the accumulated data are not sufficient, or the resulting values are often changed by some factors, other methods may be used. In other words, data is acquired from small number of recently-processed substrates. A photo-exposure time corresponds identically to the thickness of silicon-nitride films of a certain range instead of the thickness of

5   silicon-nitride films obtained successively.

As shown above, considering the pre-exposure step result, the value ET'_{n+1} from equation (4) may be changed to a corrected desired photo-exposure time $ET'(t_{n+1})$ by a feed forward process described in equation (5) below. According to equation (5), the thickness of silicon-nitride film of a pre-exposure step substrate to be processed t_{n+1} is

10   first acquired from the pre-exposure step influence prediction unit 40. An appropriate photo-exposure time $ET(t_{n+1})$ is then acquired corresponding the measured thickness of silicon-nitride film t_{n+1} to an expected photo-exposure time. In this method, feed forward is performed.

Finally, a corrected desired photo-exposure time $ET'(t_{n+1})$ is obtained by adding a

15   corrected time value ΔET_n obtained from the result of a prior task in the inspection unit 60 and an appropriate photo-exposure time. The photo-exposure unit 50 transmits a signal (preferably a photo-exposure time decision signal) so as to perform a photo-exposure during the corrected desired photo-exposure time $ET'(t_{n+1})$.

Equation (5) is the calculation method of the above example. The functional

20   relationship between the thickness of current silicon-nitride film t_n and $ET(t_n)$ of equation (5) has been inputted to the central processing unit in advance. Generally the relation

between t_n and $ET(t_n)$ is obtained by many data acquired by prior execution. These

processes may be operated in a real time through the system integrating of each

processing step. Among the units, the processing condition, target value, and the

inspection result are transferred simultaneously. It is desirable that information flow is

5   programmed in advance for a simultaneous operating.

$$ET'(t_{n+1}) = ET(t_{n+1}) + \Delta ET_n \qquad\qquad (5)$$

If the relation between the $ET(t_n)$ and t_n is not clear and a photo-exposure time for

the thickness of the silicon-nitride film of substrate is difficult to obtain, a tendency value

from a weighted average may be used as shown in equation (6) in accordance with the

10   pre-exposure step result.

$$ET(t_{n+1}) = ET'(t_n) \cdot 0.5 + ET'(t_{n-1}) \cdot 0.3 + ET'(t_{n-2}) \cdot 0.2 \qquad\qquad (6)$$

In addition, although this particular weighting scheme is used in the preferred

embodiment, different weighting schemes may be used in alternate embodiments. Such

weighting schemes may use more or less than three past exposure times, and may employ

15   different weighting factors for these exposure times.

Fig. 2 is a graph of measured line widths after development and various photo-

exposure times. In particular, Fig 2 shows the processing results before and after

applying a system for adjusting a photo-exposure time in accordance with a preferred

embodiment of the present invention. Each mark on the graph indicates a single time of

20   photo-exposure processing. On the vertical y-axis, the rectangular marks A on the upper

part indicate measured photo-exposure times, and the diamond marks B on the lower part

indicate measured line widths from after development inspections. The horizontal x-axis represents the passage of time. As shown in Fig. 2, the distribution profile is improved to about 27% than before, and the uniformity of line width comes near an average value. This can be seen by comparing the root mean square values in each region.

5   As described above, according to the preferred embodiment of the present invention, the central processing unit 70 calculates and corrects the data at a high speed, and immediately provides the result to the photo-exposure unit 50. Since the photo-exposure can then be processed by the corrected photo-exposure time, it can process according to an appropriate condition. Furthermore, the optimal photo-exposure time

10 may be obtained in advance by considering the pre-exposure step result including a correction of processing condition in a feedback way. As a result of this, a photo-exposure result pattern may be aligned more accurately.